Viral or Bacterial Infection

When a virus or bacteria (also known generically as a germ) invades your body and reproduces, it normally causes problems. Generally the germ's presence produces some side effect that makes you sick. For example, the strep throat bacteria (Streptococcus) releases a toxin that causes inflammation in your throat. The polio virus releases toxins that destroy nerve cells (often leading to paralysis). Some bacteria are benign or beneficial (for example, we all have millions of bacteria in our intestines and they help digest food), but many are harmful once they get into the body or the bloodstream.

Viral and bacterial infections are by far the most common causes of illness for most people. They cause things like colds, influenza, measles, mumps, malaria, AIDS and so on.

The job of your immune system is to protect your body from these infections. The immune system protects you in three different ways:

1. It creates a barrier that prevents bacteria and viruses from entering your body.
2. If a bacteria or virus does get into the body, the immune system tries to detect and eliminate it before it can make itself at home and reproduce.
3. If the virus or bacteria is able to reproduce and start causing problems, your immune system is in charge of eliminating it.

The immune system also has several other important jobs. For example, your immune system can detect cancer in early stages and eliminate it in many cases.

One of the funny things about the immune system is that it has been working inside your body your entire life but you probably know almost nothing about it. For example, you are probably aware that inside your chest you have an organ called a "heart". Who doesn't know that they have a heart? You have probably also heard about the fact that you have lungs and a liv-

er and kidneys. But have you even heard about your thymus? There's a good chance you don't even know that you have a thymus, yet its there in your chest right next to your heart. There are many other parts of the immune system that are just as obscure, so let's start by learning about all of the parts.

The most obvious part of the immune system is what you can see. For example, skin is an important part of the immune system. It acts as a primary boundary between germs and your body. Part of your skin's job is to act as a barrier in much the same way we use plastic wrap to protect food. Skin is tough and generally impermeable to bacteria and viruses. The epidermis contains special cells called Langerhans cells (mixed in with the melanocytes in the basal layer) that are an important early-warning component in the immune system. The skin also secretes antibacterial substances. These substances explain why you don't wake up in the morning with a layer of mold growing on your skin -- most bacteria and spores that land on the skin die quickly.

Your nose, mouth and eyes are also obvious entry points for germs. Tears and mucus contain an enzyme (lysozyme) that breaks down the cell wall of many bacteria. Saliva is also anti-bacterial. Since the nasal passage and lungs are coated in mucus, many germs not killed immediately are trapped in the mucus and soon swallowed. Mast cells also line the nasal passages, throat, lungs and skin. Any bacteria or virus that wants to gain entry to your body must first make it past these defenses.

Once inside the body, a germ deals with the immune system at a different level. The major components of the immune system are:

- Thymus
- Spleen
- Lymph system
- Bone marrow
- White blood cells
- Antibodies

- Complement system
- Hormones

Let's look at each of these components in detail.

The lymph system is most familiar to people because doctors and mothers often check for "swollen lymph nodes" in the neck. It turns out that the lymph nodes are just one part of a system that extends throughout your body in much the same way your blood vessels do. The main difference between the blood flowing in the circulatory system and the lymph flowing in the lymph system is that blood is pressurized by the heart, while the lymph system is passive. There is no "lymph pump" like there is a "blood pump" (the heart). Instead, fluids ooze into the lymph system and get pushed by normal body and muscle motion to the lymph nodes. This is very much like the water and sewer systems in a community. Water is actively pressurized, while sewage is passive and flows by gravity.

Lymph is a clearish liquid that bathes the cells with water and nutrients. Lymph is blood plasma -- the liquid that makes up blood minus the red and white cells. Think about it -- each cell does not have its own private blood vessel feeding it, yet it has to get food, water, and oxygen to survive. Blood transfers these materials to the lymph through the capillary walls, and lymph carries it to the cells. The cells also produce proteins and waste products and the lymph absorbs these products and carries them away. Any random bacteria that enter the body also find their way into this inter-cell fluid. One job of the lymph system is to drain and filter these fluids to detect and remove the bacteria. Small lymph vessels collect the liquid and move it toward larger vessels so that the fluid finally arrives at the lymph nodes for processing.

Lymph nodes contain filtering tissue and a large number of lymph cells. When fighting certain bacterial infections, the lymph nodes swell with bacteria and the cells fighting the bacteria, to the point where you can actually feel them. Swollen lymph nodes are therefore a good indication that you have an infection of some sort.

Once lymph has been filtered through the lymph nodes it re-enters the bloodstream.

Thymus

The thymus lives in your chest, between your breast bone and your heart. It is responsible for producing T-cells (see the next section), and is especially important in newborn babies - without a thymus a baby's immune system collapses and the baby will die. The thymus seems to be much less important in adults - for example, you can remove it and an adult will live because other parts of the immune system can handle the load. However, the thymus is important, especially to T cell maturation (as we will see in the section on white blood cells below).

Spleen

The spleen filters the blood looking for foreign cells (the spleen is also looking for old red blood cells in need of replacement). A person missing their spleen gets sick much more often than someone with a spleen.

Bone marrow

Bone marrow produces new blood cells, both red and white. In the case of red blood cells the cells are fully formed in the marrow and then enter the bloodstream. In the case of some white blood cells, the cells mature elsewhere. The marrow produces all blood cells from **stem cells**. They are called "stem cells" because they can branch off and become many different types of cells - they are precursors to different cell types. Stem cells change into actual, specific types of white blood cells.

White blood cells

White blood cells are described in detail in the next section.

Antibodies (also referred to as immunoglobulins and gammaglobulins) are produced by white blood cells. They are Y-shaped proteins that each respond to a specific **antigen** (bacteria, virus or toxin). Each antibody has a special section (at the tips of the two branches of the Y) that is sensitive to a specific antigen and binds to it in some way. When an antibody binds to a toxin it

is called an antitoxin (if the toxin comes from some form of venom, it is called an antivenin). The binding generally disables the chemical action of the toxin. When an antibody binds to the outer coat of a virus particle or the cell wall of a bacterium it can stop their movement through cell walls. Or a large number of antibodies can bind to an invader and signal to the complement system that the invader needs to be removed.

Antibodies come in five classes:

- Immunoglobulin A (IgA)
- Immunoglobulin D (IgD)
- Immunoglobulin E (IgE)
- Immunoglobulin G (IgG)
- Immunoglobulin M (IgM)

Whenever you see an abbreviation like IgE in a medical document, you now know that what they are talking about is an antibody.

For additional information on antibodies see The Antibody Resource Page.

The complement system, like antibodies, is a series of proteins. There are millions of different antibodies in your blood stream, each sensitive to a specific antigen. There are only a handful of proteins in the complement system, and they are floating freely in your blood. Complements are manufactured in the liver. The complement proteins are activated by and work with (complement) the antibodies, hence the name. They cause lysing (bursting) of cells and signal to phagocytes that a cell needs to be removed.

For additional information on complements, see The Complement System.

Hormones

There are several hormones generated by components of the immune system. These hormones are known generally as **lymphokines**. It is also known that certain hormones in the body suppress the immune system. Steroids and corticosteroids (components of adrenaline) suppress the immune system.

Tymosin (thought to be produced by the thymus) is a hormone that encourages lymphocyte production (a lymphocyte is a form of white blood cell - see below). Interleukins are another type of hormone generated by white blood cells. For example, Interleukin-1 is produced by macrophages after they eat a foreign cell. IL-1 has an interesting side-effect - when it reaches the hypothalamus it produces fever and fatigue. The raised temperature of a fever is known to kill some bacteria.

For additional information see Manifestations of Infection: Fever and IL-1.

Tumor Necrosis Factor

Tumor Necrosis Factor (TNF) is also produced by macrophages. It is able to kill tumor cells, and it also promotes the creation of new blood vessels so it is important to healing.

Interferon

Interferon interferes with viruses (hence the name) and is produced by most cells in the body. Interferons, like antibodies and complements, are proteins, and their job is to let cells signal to one another. When a cell detects interferon from other cells, it produces proteins that help prevent viral replication in the cell.

You are probably aware of the fact that you have "red blood cells" and "white blood cells" in your blood. The white blood cells are probably the most important part of your immune system. And it turns out that "white blood cells" are actually a whole collection of different cells that work together to destroy bacteria and viruses. Here are all of the different types, names and classifications of white blood cells working inside your body right now:

- Leukocytes
- Lymphocyte
- Monocytes
- Granulocytes
- B-cells
- Plasma cells
- T-cells
- Helper T-cells
- Killer T-cells
- Suppressor T-cells
- Natural killer cells
- Neutrophils
- Eosinophils
- Basophils
- Phagocytes
- Macrophages

Learning all of these different names and the function of each cell type takes a bit of effort, but you can understand scientific articles a lot better once you get it all figured out! Here's a quick summary to help you get all of the different cell types organized in your brain.

All white blood cells are known officially as **leukocytes**. White blood cells are not like normal cells in the body -- they actually act like independent, living single-cell organisms able to move and capture things on their own. White blood cells behave very much like amoeba in their movements and are able to engulf other cells and bacteria. Many white blood cells cannot divide and reproduce on their own, but instead have a factory somewhere in the body that produces them. That factory is the bone marrow.

Leukocytes are divided into three classes:

- Granulocytes - Granulocytes make up 50% to 60% of all leukocytes. Granulocytes are themselves divided into three classes: neutrophils, eosinophils and basophils. Granulocytes get their name because they contain granules, and these granules contain different chemicals depending on the type of cell.
- Lymphocyte - Lymphocytes make up 30% to 40% of all leukocytes. Lymphocytes come in two classes: B cells (those that mature in bone marrow) and T cells (those that mature in the thymus).
- Monocyte - Monocytes make up 7% or so of all leukocytes. Monocytes evolve into macrophages.

All white blood cells start in bone marrow as **stem cells**. Stem cells are generic cells that can form into the many different types of leukocytes as they mature. For example, you can take a mouse, irradiate it to kill off its bone marrow's ability to produce new blood cells, and then inject stem cells into the mouse's blood stream. The stem cells will divide and differentiate into all different types of white blood cells. A "bone marrow transplant" is accomplished simply by injecting stem cells from a donor into the blood stream. The stem cells find their way, almost magically, into the marrow and make their home there.

Each of the different types of white blood cells have a special role in the immune system, and many are able to transform themselves in different ways. The following descriptions help to understand the roles of the different cells.

- **Neutrophils** are by far the most common form of white blood cells that you have in your body. Your bone marrow produces trillions of them every day and releases them into the bloodstream, but their life span is short -- generally less than a day. Once in the bloodstream neutrophils can move through capillary walls into tissue. Neutorphils are attracted to foreign material, inflammation and bacteria. If you get a splinter or a cut, neutrophils will be attracted by a process called chemotaxis. Many single-celled organisms use this same process -- chemotaxis lets motile cells move toward higher concentrations of a chemical. Once a neutrophil finds a foreign particle or a bacteria it will engulf it, releasing enzymes, hydrogen peroxide and other chemicals from its granules to kill the bacteria. In a site of serious infection (where lots of bacteria have reproduced in the area), pus will form. Pus is simply dead neutrophils and other cellular debris.

- **Eosinophils and basophils** are far less common than neutrophils. Eosinophils seem focused on parasites in the skin and the lungs, while Basophils carry histamine and therefore important (along with mast cells) to causing inflammation. From the immune system's standpoint inflammation is a good thing. It brings in more blood and it dilates capillary walls so that more immune system cells can get to the site of infection.
- Of all blood cells, **macrophages** are the biggest (hence the name "macro"). Monocytes are released by the bone marrow, float in the bloodstream, enter tissue and turn into macrophages. Most boundary tissue has its own devoted macrophages. For example, alveolar macrophages live in the lungs and keep the lungs clean (by ingesting foreign particles like smoke and dust) and disease free (by ingesting bacteria and microbes). Macrophages are called langerhans cells when they live in the skin. Macrophages also swim freely. One of their jobs is to clean up dead neutrophils -- macropghages clean up pus, for example, as part of the healing process.
- The **lymphocytes** handle most of the bacterial and viral infections that we get. Lymphocytes start in the bone marrow. Those destined to become B cells develop in the marrow before entering the bloodstream. T cells start in the marrow but migrate through the bloodstream to the thymus and mature there. T cells and B cells are often found in the bloodstream but tend to concentrate in lymph tissue such as the lymph nodes, the thymus and the spleen. There is also quite a bit of lymph tissue in the digestive system. B cells and T cells have different functions.
- **B cells**, when stimulated, mature into plasma cells -- these are the cells that produce antibodies. A specific B cell is tuned to a specific germ, and when the germ is present in the body the B cell clones itself and produces millions of antibodies designed to eliminate the germ.
- **T cells**, on the other hand, actually bump up against cells and kill them. T cells known as Killer T cells can detect cells in your body that are harboring viruses, and when it detects such a cell it kills it. Two other types of T cells, known as Helper and Suppressor T cells, help sensitize killer T cells and control the immune response.

T Cells

Helper T cells are actually quite important and interesting. They are activated by Interleukin-1, produced by macrophages.

Once activated, Helper T cells produce Interleukin-2, then interferon and other chemicals. These chemicals activate B cells so that they produce antibodies. The complexity and level of interaction between neutrophils, macrophages, T cells and B cells is really quite amazing.

Because white blood cells are so important to the immune system, they are used as a measure of immune system health. When you hear that someone has a "strong immune system" or a "suppressed immune system", one way it was determined was by counting different types of white blood cells in a blood sample. A normal white blood cell count is in the range of 4,000 to 11,000 cells per microliter of blood. 1.8 to 2.0 helper T-cells per suppressor T-cell is normal. A normal absolute neutrophil count (ANC) is in the range of 1,500 to 8,000 cells per microliter. An article like Introduction to Hematology can help you learn more about white blood cells in general and the different types of white blood cells found in your body.

One important question to ask about white blood cells (and several other parts of the immune system) is, "How does a white blood cell know what to attack and what to leave alone? Why doesn't a white blood cell attack every cell in the body?" There is a system built into all of the cells in your body called the Major Histocompatibility Complex (MHC) (also known as the Human Leukocyte Antigen (HLA)) that marks the cells in your body as "you". Anything that the immune system finds that does not have these markings (or that has the wrong markings) is definitely "not you" and is therefore fair game. Encyclopedia Britannica has this to say about the MHC:

> *"There are two major types of MHC protein molecules--class I and class II--that span the membrane of almost every cell in an organism. In humans these molecules are encoded by several genes all clustered in the same region on chromosome 6. Each gene has an unusual number of alleles (alternate forms of a gene). As a result, it is very rare for two individuals to have the same set of MHC molecules, which are collectively called a tissue type. MHC molecules are important components of the immune response. They allow cells that have been invaded by an infectious organism to be detected by cells of the immune system called T lymphocytes, or T cells. The MHC molecules do this by presenting fragments of proteins (peptides) belonging to the invader on the surface of the cell. The T cell recognizes the foreign peptide attached to the MHC molecule and binds to it, an action that stimulates the T cell to either destroy or cure the infected cell. In uninfected healthy cells the MHC molecule presents peptides*

> *from its own cell (self peptides), to which T cells do not normally react. However, if the immune mechanism malfunctions and T cells react against self peptides, an autoimmune disease arises."*

See Biology of the Immune System and Major Histocompatibility Complex for additional details.

There are many diseases that, if you catch them once, you will never catch again. Measles is a good example, as is chicken pox. What happens with these diseases is that they make it into your body and start reproducing. The immune system gears up to eliminate them. In your body you already have B cells that can recognize the virus and produce antibodies for it. However, there are only a few of these cells for each antibody. Once a particlular disease is recognized by these few specific B cells, the B cells turn into plasma cells, clone themselves and start pumping out antibodies. This process takes time, but the disease runs it course and is eventually eliminated. However, while it is being eliminated, other B cells for the disease clone themselves but do not generate antibodies. This second set of B cells remains in your body for years, so if the disease reappears your body is able to eliminate it immediately before it can do anything to you.

A vaccine is a weakened form of a disease. It is either a killed form of the disease, or it is a similar but less virulent strain. Once inside your body your immune system mounts the same defense, but because the disease is different or weaker you get few or no symptoms of the disease. Now, when the real disease invades your body, your body is able to eliminate it immediately.

Vaccines exist for all sorts of diseases, both viral and bacterial: measles, mumps, whooping cough, tuberculosis, smallpox, polio, typhoid, etc.

Many diseases cannot be cured by vaccines, however. The common cold and Influenza are two good examples. These diseases either mutate so quickly or have so many different strains in the wild that it is impossible to inject all of them into your body. Each time you get the flu, for example, you are getting a different strain of the same disease.

AIDS

AIDS (Acquired Immune Deficiency Syndrome) is a disease caused by HIV (the Human Immunodeficiency Virus). This is a particularly problematic disease for the immune system because the virus actually attacks immune system cells. In particular, it reproduces inside Helper T cells and kills them in the process. Without Helper T cells to orchestrate things, the immune system eventually collapses and the victim dies of some other infection that the immune system would normally be able to handle. See How AIDS Works as well as the links below for more information.

- HIV Lifecycle
- AIDS Research
- AIDS and HIV Drugs
- AIDS/HIV Research and Treatment

Sometimes your immune system is not able to activate itself quickly enough to outpace the reproductive rate of a certain bacteria, or the bacteria is producing a toxin so quickly that it will cause permanent damage before the immune system can eliminate the bacteria. In these cases it would be nice to help the immune system by killing the offending bacteria directly.

Antibiotics work on bacterial infections. Antibiotics are chemicals that kill the bacteria cells but do not affect the cells that make up your body. For example, many antibiotics interrupt the machinery inside bacterial cells that builds the cell wall. Human cells do not contain this machinery, so they are unaffected. Different antibiotics work on different parts of bacterial machinery, so each one is more or less effective on specific types of bacteria. You can see that, because a virus is not alive, antibiotics have no effect on a virus.

One problem with antibiotics is that they lose effectiveness over time. If you take an antibiotic it will normally kill all of the bacteria it targets over the course of a week or 10 days. You will feel better very quickly (in just a day or two) because the antibiotic kills the majority of the targeted bacteria very quickly. However, on occasion one of the bacterial offspring will contain

a mutation that is able to survive the specific antibiotic. This bacteria will then reproduce and the whole disease mutates. Eventually the new strain is infecting everyone and the old antibiotic has no effect on it. This process has become more and more of a problem over time and has become a significant concern in the medical community.

Sometimes the immune system makes a mistake. One type of mistake is called **autoimmunity**: the immune system for some reason attacks your own body in the same way it would normally attack a germ. Two common diseases are caused by immune system mistakes. Juvenile-onset diabetes is caused by the immune system attacking and eliminating the cells in the pancreas that produce insulin. Rheumatoid arthritis is caused by the immune system attacking tissues inside the joints.

Allergies are another form of immune system error. For some reason, in people with allergies, the immune system strongly reacts to an allergen that should be ignored. The allergen might be a certain food, or a certain type of pollen, or a certain type of animal fur. For example, a person allergic to a certain pollen will get a runny nose, watery eyes, sneezing, etc. This reaction is caused primarily by mast cells in the nasal passages. In reaction to the pollen the mast cells release histamine. Histamine has the effect of causing inflammation, which allows fluid to flow from blood vessels. Histamine also causes itching. To eliminate these symptoms the drug of choice is, of course, an antihistamine.

The last example of an immune system mistake is the effect the immune system has on transplanted tissue. This really isn't a mistake, but it makes organ and tissue transplants nearly impossible. When the foreign tissue is placed inside your body, its cells do not contain the correct identification. Your immune system therefore attacks the tissue. The problem cannot be prevented, but can be diminished by carefully matching the tissue donor with the recipient and by using immunosuppressing drugs to try to prevent an immune system reaction. Of course, by suppressing the immune system these drugs open the patient to opportunistic infections.

For more information on the immune system and related topics, check out the links on the next page.

Related Articles

- How Anthrax Works
- How Mad Cow Disease Works
- How Viruses Work
- How SARS Works
- How Your Lungs Work
- How Blood Works
- How Cells Work

More Great Links

- The Anatomy of the Immune System
- National Cancer Institute: Understanding the Immune System
- The Immune System -- An Overview